VOLUME III: CHAPTER 2

RESIDENTIAL WOOD COMBUSTION

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INTRODUCTION

This chapter describes the procedures and recommended approaches for estimating emissions from residential wood combustion. Section 2 of this chapter contains a general description of the residential wood combustion category, and an overview of available control techniques. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation method for residential wood combustion, while Section 5 presents alternative emission estimation techniques. Quality assurance/quality control are discussed in Section 6. Data coding procedures are discussed in Section 7, and Section 8 is the reference section.

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SOURCE CATEGORY DESCRIPTION

The area source category of residential wood combustion is defined as wood burning that takes place primarily in woodstoves and fireplaces. Residential wood burning occurs either as a necessary source of heat or for aesthetics. In the 1980's, woodstoves became more popular and fireplaces became standard equipment in houses, townhouses, and some resorts. Residential wood combustion could be a significant contributor of pollution in many areas of the country, particularly in Colorado and states in New England and the Pacific Northwest. Pollutants emitted from residential wood combustion include particulate matter (PM), volatile organic compounds (VOC), hazardous air pollutants (HAPs), nitrogen oxides (NO_x) and carbon monoxide (CO).

2.1 EMISSION SOURCES

The following descriptions of wood-burning devices are derived from *AP-42* (EPA, 1996). More information about these sources can be found in the primary references and background documents for the *AP-42* sections pertaining to wood combustion, Chapter 1, Sections 9 and 10.

2.1.1 FIREPLACE TYPES

Fireplaces can be divided into 2 broad categories: (1) masonry (generally brick and/or stone, assembled on site, and integral to a structure) and (2) factory-built (usually metal, installed on site as a package with appropriate duct work).

Masonry fireplaces typically have large fixed openings to the fire bed and have dampers above the combustion area in the chimney to limit room air and heat losses when the fireplace is not being used. Some masonry fireplaces are designed or retrofitted with doors and louvers to reduce the intake of combustion air during use.

Factory-built fireplaces are commonly equipped with louvers and glass doors to reduce the intake of combustion air, and some are surrounded by ducts through which floor level air is drawn by natural or forced convection, heated, and returned to the room. Many varieties of factory-built fireplaces are now available on the market. One general class is the freestanding fireplace, the most common of which consists of an inverted sheet metal funnel and stovepipe directly above the fire bed. Another class is the "zero clearance" fireplace, an iron or heavy gauge steel firebox lined inside with firebrick and surrounded by multiple steel walls with spaces for air circulation. Some zero clearance fireplaces can be inserted into existing masonry fireplace openings, and thus are sometimes called "inserts." Some of these units are equipped with close fitting doors and have operating and combustion characteristics similar to woodstoves.

Masonry fireplaces usually heat a room by radiation, with a significant fraction of the combustion heat lost in the exhaust gases and through fireplace walls. Moreover, some of the radiant heat entering the room goes toward warming the outside air that is pulled into the residence to make up for that drawn up the chimney. The net effect is that masonry fireplaces are usually inefficient heating devices. Indeed, in cases where combustion is poor, where the outside air is cold, or where the fire is allowed to smolder (thus drawing outside air into a residence without producing appreciable radiant heat energy), a net heat loss may occur in a residence using a fireplace. Fireplace heating efficiency may be improved by a number of measures that either reduce the excess air rate or transfer back into the residence some of the heat that would normally be lost in the exhaust gases or through fireplace walls. As noted above, such measures are commonly incorporated into factory-built units. As a result, the energy efficiencies of factory-built fireplaces are slightly higher than those of masonry fireplaces.

Fireplace emissions are highly variable and are a function of many wood characteristics and operating practices. In general, conditions which promote a fast burn rate and a higher flame intensity enhance secondary combustion and thereby lower emissions. Conversely, higher emissions will result from a slow burn rate and a lower flame intensity. Such generalizations apply particularly to the earlier stages of the burning cycle, when significant quantities of combustible volatile matter are being driven out of the wood. Later in the burning cycle, when all volatile matter has been driven out of the wood, the charcoal that remains burns with relatively few emissions.

2.1.2 WOODSTOVE TYPES

Woodstoves are commonly used in residences as space heaters. They are used both as the primary source of residential heat and to supplement conventional heating systems.

There are five different woodstove categories:

- The conventional woodstove;
- The catalytic woodstove;
- The noncatalytic woodstove;
- The pellet stove; and
- The masonry heater.

Among these categories, there are many variations in device design and operation characteristics.

The conventional woodstove category comprises all woodstoves without catalytic combustors that are not included in the other noncatalytic categories (i.e., noncatalytic and pellet). Conventional stoves do not have any emission reduction technology or design features and, in most cases, were manufactured before 1988. Stoves of many different airflow designs may be in this category, such as updraft, downdraft, crossdraft, and S-flow.

Catalytic woodstoves are equipped with a ceramic or metal honeycomb device, called a combustor or converter, that is coated with noble metals such as platinum and palladium. The catalyst material reduces the ignition temperature of the unburned VOCs and CO in the exhaust gases, thus augmenting their ignition and combustion at normal stove operating temperatures. As these components burn, the temperature inside the catalyst increases to a point at which the ignition of the gases is essentially self-sustaining.

Noncatalytic woodstoves do not employ catalysts but do have emission reducing technology or features. Typical noncatalytic design includes baffles and secondary combustion zones.

Pellet woodstoves are fueled with pellets of sawdust, wood products, and other biomass materials pressed into manageable shapes and sizes. These stoves have active air flow systems and unique grate design to accommodate this type of fuel. Some pellet stove models are subject to the 1988 New Source Performance Standards (NSPS), while others are exempt due to a high air-to-fuel ratio (i.e., greater than 35-to-1).

Masonry heaters are large, enclosed chambers made of masonry products or a combination of masonry products and ceramic materials. These devices are exempt from the 1988 NSPS due to their weight (i.e., greater than 800 kg). Masonry heaters are gaining in popularity as a cleaner burning and heat efficient form of primary and supplemental heat, relative to other types of woodstoves. In a masonry heater, a complete charge of wood is burned in a relatively short period of time. The heat released is stored in the large thermal mass of masonry materials. This "stored" heat is then slowly released to the surrounding area for many hours after the fire has burned out.

2.2 FACTORS INFLUENCING EMISSIONS

2.2.1 PROCESS OPERATING FACTORS

Fireplace and woodstove emissions are highly variable and are a function of many wood characteristics and operating practices. In general, conditions which promote a fast burn rate and a higher flame intensity enhance secondary combustion and thereby lower emissions. Secondary combustion is especially important in wood burning because of the high volatile matter content of wood, typically 80 percent by dry weight. Conversely, higher emissions will result from a slow burn rate and a lower flame intensity. Such generalizations apply particularly to the earlier stages of the burning cycle, when significant quantities of combustible volatile matter are being driven out of the wood. Later in the burning cycle, when all volatile matter has been driven out of the wood, the charcoal that remains burns with relatively few emissions (EPA, 1996).

2.2.2 REGULATORY ISSUES

The Clean Air Act Amendments of 1990 (CAAA) required that all areas in the country achieve the National Ambient Air Quality Standard (NAAQS) for PM_{10} by December 31, 1994. The EPA published technical guidance for reasonably available control measures (RACM) and best available control measures (BACM) for control of particulate matter (PM) from woodstoves to achieve this goal of reducing PM_{10} emissions. Those areas that do not achieve PM_{10} attainment by December 31, 1994, must apply BACM and develop a plan to meet the NAAQS by December 31, 2001. The only exceptions are those areas that were reclassified as serious after 1990; these areas must attain the NAAQS for PM_{10} no later than the end of the tenth calendar year after the area's designation as nonattainment. The BACM requirements include combinations of the following control measures: the use of new technology woodstoves, improvements in wood burning performance (e.g., control of wood moisture content, weatherization of homes), the use of "no burn" days, public awareness and education programs, replacement or installation of gas-burning equipment in fireplaces, and total banning of burning. The use of these BACM will reduce VOC, HAPs, and CO along with PM, for measures that produce more complete combustion of wood; for measures that reduce the occurrence of combustion, NO_x will also be reduced.

Considerations for projecting emissions from residential wood combustion should include the potential applicability of RACM and/or BACM to the inventory region. Projection of emissions should also address the potential for an increase in new homes in the inventory region, since fireplaces are standard in many new homes. The future use of woodstoves is a more complicated issue that is affected by weather patterns, electricity prices, increased public awareness, environmental concerns, and socioeconomic factors.

3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATIVE METHODOLOGIES

This section discusses the methods available for calculating emission estimates from residential wood combustion and identifies the preferred emission estimation method. A discussion of the data elements needed for each method is also provided.

3.2 AVAILABLE METHODOLOGIES

The preferred and alternative methods to estimate activity factors for residential wood combustion are as follows:

- Preferred Method: Residential Wood Survey
- Alternative Method: Census Bureau and Energy Information Administration (EIA) Data Method

If an inventory is being prepared only for warm weather months--when wood burning is at a minimum, if not nonexistent--the Preferred Method described below would not be a good use of resources. In this case, the alternative method should be used.

3.3 DATA NEEDS

3.3.1 DATA ELEMENTS

The data elements required to estimate emissions from residential wood combustion depends partly on the method used and the level of detail required in the inventory.

The data elements needed to calculate emissions for this category when using the survey method are:

- Wood burned, in tons;
- Fireplace or woodstove type;

- Information needed for scaling up the inventory information (any or a combination of the following):

  - distribution of rural/urban population in inventory area
  - landuse
  - economic distribution
  - age of residences

- Information on state and local regulations; and

- Degree heating days for inventory area.

The survey should also request information on seasonal variability.

The data elements needed to calculate emissions by the Census data method are:

- Distribution of rural/urban population in inventory area or Census data on households heating with wood;

- Wood burning equipment type, if possible;

- Information on state and local regulations; and

- Degree heating days for inventory area.

3.3.2 Application of Controls

Controls for this category may be:

- Use of new technology woodstoves;

- Improvements in wood burning performance;

- Use of "no burn" periods;

- Public awareness and education programs;

- Replacement or installation of gas-burning equipment in fireplaces; and

- Total banning of burning.

An evaluation of applicable state or local regulations will give an indication of the adjustments that should be made to emission estimates calculated by the Census data method. If the survey method is used, the state and local regulations affecting this source category should be reviewed during the inventory planning stage, and the survey should be prepared so that information about new technology, lower-emitting woodstoves can be collected.

Since the use of lower-emitting woodstoves represents an irreversible process change, rule effectiveness usually can be assumed to be 100 percent for those households with the new woodstoves. However, it is unlikely that rule penetration will be 100 percent within an area. Factors that will affect rule penetration will include:

- Residences with woodstoves installed before the regulations came into effect
- The ease in which consumers can purchase and install woodstoves that do not conform to the current regulations; and
- The consumer's understanding and willingness to purchase and use the lower-emitting woodstoves.

Control efficiency is reflected in the lower emission factors of the new technology woodstoves. However, from field tests it is apparent that control efficiencies of the new, low emission stoves drop after only a few years of use if preventative maintenance is not performed (EPA, 1994b).

3.3.3 SPATIAL ALLOCATION

Spatial allocation may be needed during the inventory preparation to allocate:

- State or regional activity to local level; and
- County-level emission estimates to a modeling grid cell.

Spatial allocation issues for the Census data method are included in the description of the alternative method in Section 5. Information that is typically used for spatial allocation can also be used to develop surrogate factors for scaling up the information gathered by the survey method. Scaling up survey information is discussed in Section 4.

3.3.4 TEMPORAL RESOLUTION

Seasonal Apportioning

Residential wood combustion is strongly dependant on the season temperature. If the preferred method is used, the survey should attempt to collect information about wood burned during only the inventory months. The alternative to survey information is allocation using heating degree days.

The method for allocating residential wood burning using heating degree days is as follows:

- Obtain the number of heating degree days for the inventory season and for the entire year.
  - A heating degree day is a measure of the amount of heating necessary for a particular day. One heating degree day is registered for each degree below 65° F that the day's average temperature is.
  - This information can be obtained from state climatological offices, airport meteorology stations, or National Oceanographic and Atmospheric Administration (NOAA) climate data[a].

$$\begin{matrix}\text{Seasonal Fuel}\\\text{Consumption}\\\text{(Space Heating)}\end{matrix} = \begin{matrix}\text{Annual Fuel}\\\text{Consumption}\\\text{For Space Heating}\end{matrix} \cdot \left(\frac{\begin{matrix}\text{Number of Heating}\\\text{Degree Days in Season}\end{matrix}}{\begin{matrix}\text{Total Heating}\\\text{Degree Days Annually}\end{matrix}}\right) \qquad (2.3\text{-}1)$$

For example, if the heating degree days for an entire year in an inventory area are 2430, and the heating degree days for the inventory period (90 days) are 1800, then the apportioning factor for the inventory area is:

$$0.74 = \frac{\text{1800 inventory period heating degree days}}{\text{2430 annual heating degree days}} \qquad (2.3\text{-}2)$$

A seasonal activity factor of 0.43 can be used for the 3 month winter wood-burning season, if other approaches are not possible (EPA, 1991).

Daily Resolution

Residential wood combustion is assumed to occur seven days a week during the heating season.

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[a] See the most recent publication, which can be obtained from the National Climate Center, Asheville, NC.

3.3.5 PROJECTING EMISSIONS

Residential wood combustion is unlike many other area source categories in that population growth and development may not necessarily be reflected in growth for this source category. Projections of wood combustion activity should be based on the same factors used to spatially allocate activity.

If the survey method is used to collect activity data for this category, and the data can be broken down to types of woodstoves in use, then controls will be reflected in the emission factors used. The projection equation in this case will be:

$$EMIS_{PY} = ORATE_{BY} * GF * EMF_{PY} * \left[\frac{(200 - RE_{PY})}{100} \right] \tag{2.3-3}$$

where:

$EMIS_{PY}$	=	Projection year emissions
$ORATE_{BY}$	=	Base year activity level
GF	=	Growth factor
EMF_{PY}	=	Projection year controlled emission factor
RE_{PY}	=	Projection year rule effectiveness

Rule effectiveness is included in this equation to account for failures and uncertainties that may affect the actual performance of the control. Some woodstove designs may not need any consideration of RE. However, some designs such as woodstoves equipped with catalytic converters may degrade over time if preventive maintenance is not performed. Calculations for these woodstoves should take RE into account.

If detailed information about the types of woodstoves used, especially lower-emitting woodstoves, has not been collected, then the calculation is more complex. Estimates of the amount of wood being burned in lower-emitting woodstoves in comparison to the total amount of wood being burned are used to develop a value for rule penetration. Rule penetration, control efficiency and rule effectiveness are discussed in more depth in Chapter 1, *Introduction to Area Source Emission Inventory Development*. The equation used in this case is:

$$EMIS_{PY} = ORATE_{PY} * EMF_{PY,PC} * \left[1 - \left(\frac{CE_{PY}}{100} * \frac{RE_{PY}}{100} * \frac{RP_{PY}}{100} \right) \right] \tag{2.3-4}$$

where:

$EMIS_{PY}$	=	Projection year emissions
$ORATE_{PY}$	=	Projection year activity level
$EMF_{PY,PC}$	=	Projection year precontrol emission factor
CE_{PY}	=	Projection year control efficiency
RE_{PY}	=	Projection year rule effectiveness
RP_{PY}	=	Projection year rule penetration

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PREFERRED METHOD FOR ESTIMATING EMISSIONS

The preferred method for calculating emission estimates from residential wood combustion is a survey of residences in the inventory area. The main steps in developing an emission estimate through a survey are: (1) survey planning, (2) survey preparation, (3) survey distribution, (4) survey compilation and scaling, and (5) emission estimation. These steps will be discussed below.

4.1 SURVEY PLANNING

Planning a survey for this source category will include many of the same survey considerations discussed in Chapter 1, *Introduction to Area Source Emission Inventory Development* under Surveys, in Section 6. However, some source-specific issues apply. An example of a multi-state survey of resident wood fuel use can be found in *Residential Fuelwood Consumption and Production in the Plains States, 1994* (USDA, 1996). A survey of residences will need to be a representative sample of all of the residences in the inventory area so that information gathered on residential combustion can be scaled up (refer to the *EIIP QA* volume for more information on scaling up surveys). Issues that should be determined at this stage are:

- The necessary sample size;
- The number of surveys that will need to be sent in order to achieve the sample size;
- The demographic factors that will be used to scale up the survey results to the entire survey area, including how to collect that information; and
- The level of detail needed, for instance:
    - Is the inventory for an average day, an average week, or the entire season, thus requiring activity data for one of those time periods?

- Should the inventory include information about the use of controls or other factors that would require data on the different types of woodstoves being used?

Details about how to conduct a residential wood burning survey may be obtained by contacting the state and local air pollution agencies in the areas of high wood burning in the U.S. (e.g., Seattle, Washington; Portland, Oregon; Denver, Colorado; or Montana).

4.2 SURVEY PREPARATION

Survey questions should be tailored to suit the inventory region and the needs of the inventory. General points that should be included in a survey sent to a representative sample of residences are:

- An explanation of why the survey is necessary, and how more information is beneficial to the public;

- Questions that request the information needed to scale up the inventory (this should be simple, a zip code may suffice); and

- An attachment that describes the different woodstove types.

Example questions for a residential wood survey are shown in Example 4-1.

4.3 SURVEY DISTRIBUTION

Survey distribution will be determined by the budget for this category. Surveys can be distributed by a mailing, or the information can be collected through a telephone survey. Initial contacts and followup contacts may also be undertaken as part of the survey. Survey distribution issues are discussed in Chapter 1, *Introduction to Area Source Emission Inventory Development* under Surveys, in Section 6.

4.4 SURVEY COMPILATION AND SCALING

Survey compilation and scaling is discussed in the *EIIP QA* volume of this series.

Scaling up the survey may be done using the following types of information:

- Distribution of rural/urban population in inventory area;

- Landuse;
- Household economic distribution; and
- Age of residences.

Example 4-1

- Do you have a fireplace or woodstove? (If not, please return the survey without answering any more questions)
- What type of wood-burning equipment do you have? (See descriptions of woodstove types at the end of this survey)
  - Fireplace
  - Conventional woodstove
  - Noncatalytic woodstove
  - Catalytic woodstove
  - Pellet stove
  - Masonry heater
  - Woodstove, do not know what type
- How often do you burn wood in a winter week?
  ____ times per week ____ all week
- How much wood do you burn in an average winter week?
  ____ cords* (example: 1/4 cord)
- How often do you burn wood in the rest of the year, per week?

***Note:** One cord is equal to a stack of wood 4x4x8 feet. One full-size pickup truck load is about one-half of a cord
.

Planning prior to the survey should include an investigation of the best surrogate for scaling the survey information. Then, the survey can request the necessary information.

In addition to the QA/QC issues common to all survey efforts, checks should be put into place for the woodstove types entered and the amount of wood used. These entries will probably be the most likely to be in error. The conversion from wood used in cords to wood used in tons, which is dependant on wood species, could also be a source of error.

4.4.1 EMISSION ESTIMATION

After data from the surveys have been compiled and scaled up to the inventory area, the resulting activity data, in the form of wood burned in tons for each equipment type, should then be applied to emission factors provided in Tables 2.4-1 through 2.4-3. Residential woodstoves are classified as Phase I, Phase II and Pre-Phase I. Phase II stoves are those certified to meet the July 1, 1990, EPA standards; Phase I stoves meet only the July 1, 1988, EPA standards; and Pre-Phase I stoves do not meet any of the EPA standards but in most cases do necessarily meet the Oregon 1986 certification standards. *AP-42* contains PM-10 and CO emission factors for catalytic and noncatalytic woodstoves in each of these classifications, but only emission factors for Phase II are presented here. Information on how the *AP-42* emission factors were developed can be found in the *AP-42* woodstoves section. Factors from the latest edition AP-42 should be used for emission estimates. At the time of this writing, no factors for PM-2.5 are available. If PM-2.5 emission estimates are required for an inventory, it can be assumed that all of the PM-10 is PM-2.5 (EPA, 1997). Emissions estimated using this assumption should not be perceived to be of the same level of quality as the factors found in *AP-42*, and if new *AP-42* factors became available, they should supersede emission factors that are presented here.

Table 2.4-4 gives density conversion factors for hardwoods and softwoods by typical forest type within a region. These generalized factors represent a weighted average density of the three most common (in terms of volume) softwood or hardwood species within the forest type. Forest types are identified by the primary tree species or tree species groups, but will include other tree species that are typically found in that biome. Local or state forestry service personnel should be able to identify an typical forest type for an area. Although densities for softwoods are provided, it is most likely that wood used for fuel will be hardwoods.

One cord of wood can be assumed to be about 79 cubic feet of solid wood (no air spaces). *AP-42* Appendix A also contains more general conversion factors. The more detailed factors in Table 2.4-4 are preferred.

TABLE 2.4-1

CRITERIA POLLUTANT EMISSION FACTORS FOR RESIDENTIAL WOOD COMBUSTION (LB/TON)[a]

Process Description	Criteria Pollutant Emission Factors				
	PM_{10}	NO_x	CO	VOC	SO_x
Residential Total Woodstoves and Fireplaces[b]	34.6	2.6	252.6	229.0	0.4
Residential Fireplaces[c]	34.6	2.6	252.6	229.0	0.4
Residential Woodstoves - Catalytic Phase II	16.2	2.0	107.0	15.0	0.4
Residential Woodstoves - Noncatalytic Phase II	14.6		140.8	12.0	0.4
Residential Woodstoves - Conventional	30.6	2.8	230.8	53.0	0.4
Residential Woodstoves - Pellet/Certified[d]	4.2	13.8	39.4		0.4
Residential Woodstoves - Pellet/Exempt[e]	8.8		52.2		
Masonry Heaters[f]	5.6		149.0		

[a] Source: EPA, 1996.
[b] These emission factors are for fireplaces and should be used when information separating wood burning equipment types is not available.
[c] Exempt from the 1988 New Source Performance Standards for woodstoves because of air: fuel ratio > 15:1 and/or minimum burn rate > 5 kg/hr.
[d] Certified pursuant to the 1988 New Source Performance Standards for woodstoves.
[e] Exempt from the 1988 New Source Performance Standards for woodstoves because of air: fuel ratio >35:1.
[f] Exempt from the 1988 New Source Performance Standards for woodstoves because of weight > 800 kg.

TABLE 2.4-2

HAP EMISSION FACTORS FOR RESIDENTIAL WOOD COMBUSTION (LB/TON)[a]

HAP	Woodstove Type		
	Conventional	**Noncatalytic**	**Catalytic**
Benzene	1.94E-00		1.46E-00
Cadmium	2.2E-05	2.0E-05	4.6E-05
Chromium	<1.0E-06	<1.0E-06	<1.0E-06
Manganese	1.7E-04	1.4E-04	2.2E-04
Methyl Ethyl Ketone	2.9E-01		6.0E-02
Nickel	1.4E-05	2.0E-05	2.2E-06
Phenol		<1.0E-03	
Toluene	7.3E-01		5.2E-01
O-Xylene	2.0E-01		1.9E-01

[a] Source: EPA, 1996

TABLE 2.4-3

POLYCYCLIC AROMATIC HYDROCARBON (PAH) EMISSION FACTORS FOR RESIDENTIAL WOOD COMBUSTION (LB/TON)[a]

	Stove Type			
Pollutant	**Conventional**	**Noncatalytic**	**Catalytic**	**Exempt Pellet[b]**
PAH				
Acenaphthene	0.010	0.010	0.006	
Acenaphthylene	0.212	0.032	0.068	
Anthracene	0.014	0.009	0.008	
Benzo(a)Anthracene	0.020	<0.001	0.024	
Benzo(b)Fluoranthene	0.006	0.004	0.004	2.60 E-05
Benzo(g,h,i)Fluoranthene		0.028	0.006	
Benzo(k)Fluoranthene	0.002	<0.001	0.002	
Benzo(g,h,i)Perylene	0.004	0.020	0.002	
Benzo(a)Pyrene	0.004	0.006	0.004	
Benzo(e)Pyrene	0.012	0.002	0.004	
Biphenyl		0.022		
Chrysene	0.012	0.010	0.010	7.52 E-05
Dibenzo(a,h)Anthracene	0.000	0.004	0.002	
7,12-Dimethylbenz(a)Anthracene		0.004		
Fluoranthene	0.020	0.008	0.012	5.48 E-05
Fluorene	0.024	0.014	0.014	
Indeno(1,2,3,cd)Pyrene	0.000	0.020	0.004	
9-Methylanthracene		0.004		
12-Methylbenz(a)Anthracene		0.002		
3-Methylchlolanthrene		<0.001		
1-Methylphenanthrene		0.030		
Naphthalene	0.288	0.144	0.186	
Nitronaphthalene		0.000		
Perylene		0.002		
Phenanthrene	0.078	0.118	0.048	3.32 E-05
Phenanthrol		0.000		
Phenol		<0.001		
Pyrene	0.024	0.008	0.010	4.84 E-05
PAH Total	0.730	0.500	0.414	

[a] Source: EPA, 1996

[b] Only the woodstoves exempt from the 1988 New Source Performance Standards for woodstoves because of air fuel ratio > 35:1.

TABLE 2.4-4

FACTORS TO CONVERT WOOD VOLUME (CUBIC FEET) TO WEIGHT (POUNDS) (EPA, 1995)

Region	Forest Type	Density Conversion Factors	
		Softwood	Hardwood
Southeast and South Central	Pines	31.8	39.9
	Oak-Hickory	33.4	39.9
	Oak-Pine	32.6	39.9
	Bottomland Hardwoods	28.7	36.2
Northeast and Mid Atlantic	Pines	23.6	33.8
	Spruce-Fir	23.0	32.8
	Oak-Hickory	23.3	39.7
	Maple-Beech-Birch	24.0	37.4
	Bottomland Hardwoods	28.7	36.2
North Central and Central	Pines	26.3	33.1
	Spruce-Fir	21.9	30.0
	Oak-Hickory	26.0	39.4
	Maple-Beech	23.2	35.9
	Aspen-Birch	23.1	29.0
	Bottomland Hardwoods	28.7	36.2
Rocky Mountain and Pacific Coast	Douglas Fir	29.5	23.7
	Ponderosa Pine	26.0	23.7
	Fir-Spruce	21.8	23.7
	Hemlock-Sitka Spruce	27.1	27.0
	Lodgepole Pine	26.4	23.7
	Larch	31.7	27.0
	Redwoods	26.0	36.2
	Hardwoods	26.5	24.0

5

ALTERNATIVE METHOD FOR ESTIMATING EMISSIONS

The alternative method to estimate activity factors for residential wood combustion uses information on residential wood data compiled by state or federal agencies, and apportioned using data from the U.S. Census Bureau and the U.S. Energy Information Administration. The emission factors used for the preferred method are also used for the alternative method.

The preferred source of information on residential wood burning is the state energy office, or state forest service. Available information may be estimates of wood burned for residential heating at the state, regional or county level. Inventory personnel should try to collect the most detailed and area-specific information possible.

If the state energy office does not have information on residential wood burning, other sources of information for area-wide wood use, or per household wood use should be identified. USDA Forest Service regional experiment stations may compile information that may be useful. One such document is a special study prepared by the North Central Forest Experiment Station in St. Paul, Minnesota (USDA, 1996). This study compiled residential wood use statistics for Kansas, Nebraska, North Dakota, and South Dakota, including average per household fuelwood consumption.

Other information resources are documents compiled by the U.S. Department of Energy (DOE), Energy Information Administration (EIA). Statistics for wood fuel use can be found in the EIA's *Household Energy Consumption and Expenditures*[a], published triennially, and state wood use data can be found in the *State Energy Data Report*, which is published annually by the EIA.

[a] See the publication for the year closest to the inventory year, which can be obtained from the U.S. DOE, EIA, Washington, DC. The EIA maintains a Web site at: http://www.eia.doe.gov/index.html.

The wood burned at the state level is apportioned to the county level using U.S. Census[a] data on households that use wood as a primary fuel. The equation is:

$$\text{County Wood Use} = \text{State Wood Use} * \frac{\text{County Wood–Burning Households}}{\text{State Wood–Burning Households}} \quad (2.5\text{-}1)$$

State level wood use (in cords) is available in the EIA's *State Energy Data Report*. State and county statistics on wood-burning households are available from the U.S. Census Bureau. Cords of wood are converted to pounds of wood using factors in Table 2.4-4 or *AP-42* Appendix A. Example 5-1 shows this process for one county.

If desired, determine the type of wood burning equipment in the inventory region by performing a survey to apportion the wood used in fireplaces and woodstoves, by type.[b] In some areas with homogeneous housing (by age and economic level), a survey of a representative number of households can be performed and scaled-up to the inventory area. Information on the use of new technology woodstoves can be obtained from the state environmental agency, woodstove vendors in the area, and the Hearth Products Association.[c]

5.1 Emission Factors

The preferred emission factors for estimating emissions from residential wood combustion are shown in Tables 2.4-1 through 2.4-3. Emission factors for the relevant criteria pollutants are shown in Table 2.4-1; emission factors for the relevant HAPs are shown in Tables 2.4-2 and 2.4-3. When information about the different woodstove types is not available, use the emission factors for conventional woodstoves. If no distinction has been made between fireplaces and woodstoves, use the emission factors for fireplaces.

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[a] See the publication for the year closest to the inventory year, which can be obtained from the U.S. Commerce Department, Census Bureau. The Census Bureau also maintains a Web Site which allows for interactive queries of Census data: http://venus.census.gov/cdrom/lookup. The Census Summary Tape File 3 (STF3A) contains this information.

[b] Conventional, catalytic, noncatalytic (new technology), masonry, or pellet fired.

[c] Located in Washington, DC.

Example 5-1:

For a 1993 inventory, the wood used in State A is obtained from the EIA's *State Energy Data Report* for that year. The wood used for residential energy is listed in Table 18, Residential Energy Consumption Estimates, under the classification of Biofuels, and is 622 thousand cords. U.S. Census data on house heating fuel is available for the year 1990, and that data will be used to apportion the state wood use data to the county level. There are 80,047 households using wood as a primary fuel at the state level, and 1242 households using wood as a primary fuel at the county level. To apportion the state level wood usage:

$$\begin{aligned}\text{County Wood Use} &= 622{,}000 \text{ cords} * \frac{1{,}242}{80{,}047} \\ &= 9{,}651 \text{ cords}\end{aligned}$$

To calculate the wood weight from the number of cords, one cord is estimated to be about 79 ft^3 solid wood (air spaces are removed). State A is a southeastern state, so the specific gravity of the wood is estimated to be 0.639 for a southeastern hardwood, and the specific gravity is multiplied by the weight of a cubic foot of water (62.4 lbs). The calculation is:

$$\begin{aligned}\text{Wood Weight} &= 9{,}651 \text{ cords} * 79 \text{ ft}^3 * 0.639 * 62.4 \text{ lb} \\ &= 30{,}400{,}789 \text{ lb} \\ &= 15{,}200 \text{ tons}\end{aligned}$$

5.2 SPECIAL EMISSION CALCULATION ISSUES

To calculate wood use for a season day from annual wood use, the wood used for heating should be separated from wood used for other year-round purposes and apportioned to the season according to the number of days where space heating is needed. The method is as follows:

If wood is used for appreciable amounts of water heating and cooking as well as space heating in an inventory area, a survey should be performed to apportion wood use between space heating and the other uses. The use of wood for cooking and water heating is negligible in most regions.

The use of wood for space heating can be apportioned from the annual amount of wood burned to that burned for a season-day by one of the methods listed in Section 3 under *Temporal Resolution*. These methods are, in order of preference:

- Survey of residences;
- Heating degree days allocation; and
- Seasonal activity factor.

Section 3 discusses the heating degree day and seasonal activity factor methods.

6

QUALITY ASSURANCE/QUALITY CONTROL

During the inventory planning process, the agency should define the data quality objectives for the inventory, and set data quality goals for the emission estimates developed for this source category. Quality assurance and quality control methods may vary based on the data quality objectives for the inventory. The Quality Assurance Source Document of this series of volumes discusses methods to be used to ensure the development of a quality inventory. Quality assurance for area source inventories is also discussed in Chapter 1, *Introduction to Area Source Emission Inventory Development*, of this volume.

When using the preferred survey method, the survey method, sample design, and data handling should be planned and documented in the Quality Assurance Plan. Special care should be taken when compiling surveys for this source to ensure that equipment types are properly assigned, that wood use units are correct, and conversions of wood use are correct. When using the alternative method, data handling for all activity and emission factor data should be planned and documented in the Quality Assurance Plan.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

The preferred method will produce the most accurate and detailed estimate of emissions; however, surveys can be an expensive undertaking. Furthermore, the success of the survey depends heavily on the rate and completeness of the responses. The level of effort required for the Census data method is considerably lower, but the potential accuracy and detail in regard to the equipment type in use will be lower.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for each method are summarized in Tables 2.6-1 and 2.6-2. All scores assume that good QA/QC measures are performed and no deviations from good inventory practice have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance provided in the QA Source Document.

TABLE 2.6-1

PREFERRED METHOD DARS SCORES: LOCAL SURVEY OF A SAMPLE OF RESIDENCES

Attribute	Scores		
	Factor	**Activity**	**Emissions**
Measurement	5	7.5	0.375
Source Specificity	7	7	0.49
Spatial	9	8	0.72
Temporal	9	8	0.72
Composite Scores	0.75	0.76	0.58

Comments: Temporal scores will go down for the factors as time increases (i.e., the further you get from survey date).

TABLE 2.6-2

ALTERNATIVE METHOD DARS SCORES: NATIONAL EMISSION FACTORS AND APPORTIONED CENSUS BUREAU ACTIVITY

Attribute	Scores		
	Factor	**Activity**	**Emissions**
Measurement	5	6	0.3
Source Specificity	5	6	0.3
Spatial	9	3-6	0.27-0.54
Temporal	9	7.5	0.68
Composite Scores	0.7	0.23-0.64	0.16-0.46

Both of the methods presented in this chapter use the same emission factors, so the DARS scores for the emission factor attributes are the same, except for the source specificity category. The Census data activity method will not provide information about the types of woodstoves in use in an area. If a limited survey is performed to provide that level of detail, then source specificity will be equivalent to that for the preferred method. The key difference between the two methods is the collection of the activity data, and in particular, assigning activity to the correct location.

6.1.2 Sources of Uncertainty

Another way to assess the emission estimates is to look at the associated uncertainty. For estimates derived from survey data, the uncertainty can be quantified (see the QA Source Document, Chapter 4). Statistics needed to quantify the uncertainty for emissions derived by the Census data activity method are incomplete.

The uncertainty for emission estimates derived from the survey method is affected by several variables. These variables are:

- The sample size;
- Whether the surrogate used for scaling up the survey data is appropriate for the source category activity;
- Accurate description of the woodstove type;
- Accurate estimation and unit conversion for the wood burned; and
- Unquantifiable degradation of the control efficiency of lower emission woodstoves, especially catalytic woodstoves (EPA, 1994b).

Uncertainty of emission estimates developed by using the Census data method depend on the level of detail that the inventory preparer goes to in collecting activity information. The activity can be viewed as a combination of information, all of which could be more or less reliable. This method requires:

- An estimate of wood use in the state or region;
- Information that can be used to apportion the wood use to the inventory area, and to the individual counties within the inventory area;
- The choice of collecting woodstove type information in the inventory area; and

- The choice of using survey, heating degree days or a seasonal activity factor for seasonal apportioning of the emission estimates.

Thus, decisions regarding the source and quality of the state or regional wood use data, and the spatial and temporal apportioning will determine the uncertainty of the resulting emission estimates.

7

DATA CODING PROCEDURES

This section describes the codes available to characterize residential wood combustion emission estimates. Consistent categorization and coding will result in greater uniformity between inventories. Inventory planning for data collection calculations and inventory presentation should take the data formats presented in this section into account. Available codes and wood-burning equipment definitions may impose constraints or requirements on the preparation of emission estimates for this category.

7.1 PROCESS SOURCE CODES

The source category process codes for residential wood combustion operations are shown in Table 2.7-1. These codes are derived from the EPA's Aerometric Information Retrieval System (AIRS) AMS source category codes (EPA, 1994a).

Since controls for this source category are based on the wood burning equipment type used, and source category codes are available for those equipment types, no control codes are necessary.

TABLE 2.7-1

AIRS AMS CODES FOR RESIDENTIAL WOOD COMBUSTION

Area Source Category	Process Description	AMS Code	Units
Residential Wood Combustion	Residential Total Woodstoves and Fireplaces	21-04-008-000	Tons
	Residential Fireplaces	21-04-008-001	Tons
	Residential Woodstoves-Total	21-04-008-010	Tons
	Residential Woodstoves-Catalytic	21-04-008-030	Tons
	Residential Woodstoves-Noncatalytic	21-04-008-050	Tons
	Residential Woodstoves-Conventional	21-04-008-051	Tons
	Residential Woodstoves-Pellet-Fired	21-04-008-053	Tons

8

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